

CLAIMS:

1. A method of providing a synchronized multichannel universal serial bus, comprising:
 - 5 supplementing the signal channels in the USB specification to provide synchronization information from an external source.
2. A method as claimed in claim 1, wherein said
 - 10 synchronization information includes a trigger signal and a clock signal.
3. A synchronized multichannel universal serial bus comprising circuitry to observe USB traffic and to lock a
 - 15 local clock signal of a USB device to a periodic signal contained in USB data traffic.
4. A universal serial bus as claimed in claim 3, wherein said circuitry is adapted to lock said local clock signal
 - 20 to said periodic signal in phase, in frequency, or in both phase and frequency.
5. A universal serial bus as claimed in claim 3, wherein said circuitry is operable to decode and lock to a
 - 25 periodic data structure.
6. A universal serial bus as claimed in claim 5, wherein said circuitry is operable to decode and lock to USB Start of Frame packet tokens.
 - 30
7. A method of synchronizing a multichannel universal serial bus, comprising:
 - observing USB traffic; and
 - locking a local clock signal of a USB device to a
 - 35 periodic signal contained in USB data traffic;
 - wherein said locking is in respect of phase, of frequency, or of both phase and frequency.

8. A synchronized multichannel universal serial bus having circuitry to observe USB traffic at a plurality of points in a USB tree and to measure a round trip time of each of a plurality of individual packets, to obtain relative phases of individual USB devices in said tree.

9. A universal serial bus as claimed in claim 8, wherein said circuitry is operable to measure the roundtrip time of an ACK packet associated with a particular transaction, whereby the relative phase of each device's local clock can be controlled so that all attached USB devices can be synchronized.

10. A method of synchronizing a multichannel universal serial bus, comprising:
observing USB traffic at a plurality of points in a USB tree;
measuring a round trip time of each of a plurality of individual packets; and
determining relative phases of individual USB devices in said tree from said respective round trip times;
whereby any phase offsets of said respective individual USB devices can be adjusted according to said determined relative phases.

11. A method of providing a synchronized multichannel universal serial bus comprising:
issuing all devices in a USB topology with a trigger signal.

12. A method as claimed in claim 11, wherein said trigger signal synchronously initiates or ceases operations on a plurality of devices.

13. A method as claimed in claim 11, further including

producing said trigger signal by using a Start of Frame packet, to trigger a transducer at a given time.

14. A method as claimed in claim 11, including executing
5 said operation in phase with a local oscillator.

15. A synchronized multichannel universal serial bus,
comprising:
circuitry for issuing all devices in a USB
10 topology with a trigger signal.

16. A synchronized multichannel universal serial bus,
comprising circuitry and logic to supply synchronization
signals to USB devices at frequencies that correspond to
15 national standards.

17. A synchronized multichannel universal serial bus
comprising a USB back plane for providing to attachable
devices any one or more of USB signals, power, sockets and
20 synchronization information.

18. A method for locking the local clock of each of a
plurality of USB devices within the same USB tree to
substantially the same frequency, comprising:
25 generating or designating specific signal
structures for transmission in the USB data traffic;
transmitting said specific signal structures to
said USB device in a predefined sequence;
monitoring USB signals local to said USB device
30 for said specific signal structures;
generating a local reference signal at each of
said USB devices from said specific signal structures; and
locking the frequency of said local clock signal
at each of said USB devices to said local reference signal
35 to a predetermined degree.

19. A method as claimed in claim 18, wherein said

specific signal structures are the USB Start of Frame packet token sequences as defined in the USB specification.

5 20. A method as claimed in claim 18, wherein said specific signal structures are command sequences sent to the USB device or data sequences sent to the USB device.

10 21. A method as claimed in claim 18, further including generating said local reference signal for each of said specific signal structures.

15 22. A method as claimed in claim 18, further including generating said local reference signal for substantially all of said specific signal structures.

20 23. A method as claimed in claim 18, wherein said local clock frequency is substantially the same as said local reference signal frequency.

24. A method as claimed in claim 18, wherein said locking of each of said local clock signals to said reference signal is for the purpose of generating a frequency with a stability better than that required for pure transfer of data between a host and a respective USB device.

25 25. A method as claimed in claim 18, further including passively synchronizing said USB devices to an arbitrary degree by attachment said USB devices to a common USB hub by cables of substantially equal length.

26. A method of measuring the propagation time of signals from a USB host to a USB device within a USB tree, comprising:

35 designating a master USB device in said USB tree;
 generating or designating specified signal structures for transmission in the USB data traffic;

transmitting said specified signal structures to said USB device in a predefined sequence;

monitoring said USB traffic by means of said master USB device for said specified signal structures and
5 for specified response signals from said USB device;

generating event triggering signals local to said master USB device corresponding to decoding of said specified signal structures;

generating event triggering signals local to said
10 master USB device corresponding to decoding of response signals from said USB device;

measuring a time interval between said event triggering signals in said master USB device; and

determining a propagation time from said USB host
15 to said USB device from said time interval.

27. A method as claimed in claim 26, wherein said master USB device is attached near the top of said USB tree.

20 28. A method as claimed in claim 26, further including transmitting said specified signal structures to said USB device in said predefined sequence.

29. A method as claimed in claim 26, wherein said
25 specified signal structures comprise OUT tokens, IN tokens, ACK tokens, NAK tokens, STALL tokens, PRE tokens, SOF tokens, SETUP tokens, DATA0 tokens, DATA1 tokens, or programmable sequences bit patterns in the USB data packets.

30 30. A method as claimed in claim 26, wherein said USB device is one of a plurality of USB devices, and said method includes determining a respective propagation time for each of said USB devices including statistically
35 analyzing a plurality of such propagation determinations to improve accuracy of said propagation delay measurement.

31. A method of determining the relative propagation delay of electrical signals or data structures between a plurality of USB devices connected to a common USB host, comprising:

- 5 determining respective propagation delays between each of said USB devices and said USB host according to the method of claim 26;
- designating one of said USB devices as a temporal reference device; and
- 10 determining the difference in said propagation delay between said temporal reference device and each of said plurality of said USB devices.

32. A method of synchronizing the local clocks of each of a plurality of USB devices connected to a common USB host via a USB tree so that said clocks are substantially in phase and at substantially the same frequency, comprising:

- locking the local clock of each of said USB devices to substantially the same frequency according to the method of claim 18;
- 20 determining the relative propagation delay of signals from said USB host to each of said USB devices with respect to a selected one of said USB devices according to the method of claim 26, said selected one of said USB devices designated a reference USB device;
- determining the relative phase of said local clock of each of said plurality of USB devices with respect to said local clock of said reference USB device according to the method of claim 31;
- 30 determining the temporal adjustment or phase offset of each of said local clocks required to result in said plurality of local clocks across said USB tree being substantially in phase;
- transmitting said temporal adjustment or phase offset from said USB host to said USB devices; and
- 35 providing phase adjustment of said local clock on each of said USB devices according to said temporal

adjustment or phase offset respectively.

33. A method as claimed in claim 32, wherein each of the local clocks of at least some of said USB devices are
5 shifted in phase by a desired amount, resulting in an array of USB devices with local clocks of known relative phases.

34. A method for synchronously triggering and thereby
10 initiating or stopping one or more processes on a plurality of USB devices connected to a common USB host according to a predefined trigger command, comprising:
synchronizing the local clocks of each of said USB devices according to the method of claim 32;
15 transmitting a predetermined trigger request signal and a predetermined trigger command signal in the USB data traffic, indicative respectively of a trigger request and of said trigger command;
monitoring said USB data traffic local to each of
20 said USB devices for said trigger request signal and for said trigger command signal;
sending an initiating trigger request signal by means of said USB host to each of said USB devices to prepare said USB devices to execute said trigger request
25 at substantially the same time;
configuring said USB devices to respond to said initiating trigger request signal by preparing themselves to perform said processes on receipt said trigger signal;
configuring said USB host to issue said trigger
30 command to each of said plurality of said USB;
decoding said trigger command by means of said USB devices;
configuring said USB devices to execute said processes at substantially the same time; and
35 whereby one or more processes within said USB devices can be initiated or stopped upon receipt of said trigger command signal from said USB host.

35. A method as claimed in claim 34, wherein said trigger request signal comprises any of the USB packet signal structures defined in the USB specification, command
5 sequences sent to the USB device, or data sequences sent to the USB device.

36. A method as claimed in claim 34, including
10 transmitting said trigger request signal and said trigger command signal in a predetermined sequence.

37. A method as claimed in claim 34, wherein said trigger command signal comprises any of the USB packet signal structures defined in the USB specification, command
15 sequences sent to the USB device, or data sequences sent to the USB device.

38. A method as claimed in claim 34, wherein said local USB decoding device is a microcontroller, a
20 microprocessor, a field programmable gate array or any other element capable of decoding data structures within said USB.

39. A method according to claim 34, wherein said trigger
25 request signal comprises OUT tokens, IN tokens, ACK tokens, NAK tokens, STALL tokens, PRE tokens, SOF tokens, SETUP tokens, DATA0 tokens, DATA1 tokens, or programmable sequences bit patterns in the USB data packets.

30 40. A method according to claim 34, wherein said initiating trigger request signal comprises OUT tokens, IN tokens, ACK tokens, NAK tokens, STALL tokens, PRE tokens, SOF tokens, SETUP tokens, DATA0 tokens, DATA1 tokens, or
programmable sequences bit patterns in the USB data
35 packets.

41. A method according to claim 34, wherein said trigger

command is encoded into said USB traffic using a signal protocol defined within the USB specification.

42. A method according to claim 18, wherein each of said
5 USB devices receives a clock signal from an external source.

43. A method according to claim 42, wherein said clock
signals are received through an additional electrical or
10 optical connector, or through wireless means.

44. An apparatus for locking the local clock of each of a plurality of USB devices within the same USB tree to substantially the same frequency, comprising:

15 a signal generator for generating specific signal structures in the USB data traffic, for transmitting said specific signal structures to said USB device in a predefined sequence, and for generating a local reference signal at each of said USB devices from said specific
20 signal structures; and

a signal monitor for monitoring USB signals local to said USB device for said specific signal structures;
whereby said frequency of said local clock signal at each of said USB devices can be locked to said local
25 reference signal to a desired degree.

45. An apparatus for measuring the propagation time of signals from a USB host to a USB device within a USB tree, comprising:

30 a master USB device comprising one of the USB devices in said USB tree;

a signal generator or root hub for generating specified signal structures in the USB data traffic, for transmitting said specified signal structures to said USB
35 device in a predefined sequence;

a signal monitor for monitoring said USB traffic by means of said master USB device for said specific

signal structures and for said response signals; and
a timer for measuring a time interval between
said event triggering signals in said master USB device;
and

5 whereby a propagation time from said USB host to
said USB device can be determined from said time interval.

46. An apparatus for determining the relative propagation
delay of electrical signals or data structures between a
10 plurality of USB devices connected to a common USB host,
comprising:

an apparatus for determining respective
propagation times between each of said USB devices and
said USB host as claimed in claim 45; and

15 computing means for determining the difference in
said propagation times between a reference USB device and
each of said plurality of said USB devices.

wherein said reference USB device comprises one
of said USB devices.

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47. An apparatus for synchronizing the local clocks of
each of a plurality of USB devices connected to a common
USB host via a USB tree so that said clocks are
substantially in phase and at substantially the same
25 frequency, comprising:

an apparatus for locking said local clock of each
of said USB devices to substantially the same frequency as
claimed in claim 44;

an apparatus for determining the relative
30 propagation delay of signals from said USB host to each of
said USB devices with respect to a reference USB device
and for determining the relative phase of said local clock
of each of said plurality of USB devices with respect to
said local clock of said reference USB device as claimed
35 in claim 46, said reference USB device comprising a
selected one of said USB devices; and

a timer for determining the temporal adjustment

or phase offset of each of said local clocks required to result in said plurality of local clocks across said USB tree being substantially in phase;

5 wherein said apparatus is adapted to transmit said temporal adjustment or phase offset from said USB host to said USB devices and to provide phase adjustment of said local clock on each of said USB devices according to said temporal adjustment or phase offset respectively.

10 48. An apparatus for providing synchronous operation of a plurality of USB devices at any connection point within a common USB expansion hub, operable to perform the method of any one of claims 1 to 43.

15 49. An apparatus for providing real-time operation of one or more USB devices at any connection point within a USB expansion hub, operable to perform the method of any one of claims 1 to 43.

20 50. An apparatus for providing real-time automated control and data acquisition functions using one or more USB devices at any connection point within a USB expansion hub, operable to perform the method of any one of claims 1 to 43.